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An approximate approach to the evaluation of the anomalous magnetic moment of the neutron

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From the point of view of the experimental data (Olson *et al* 1961, Schopper 1961) concerning the electromagnetic structure of neutron the only conception that has been preserved is that the anomalous magnetic moment of the neutron is associated with the virtual pion cloud surrounding the central positive core. The major portion of the anomalous magnetic moment of the neutron is concentrated in the inner *isovector cloud* which corresponds to virtual pions.

Among theoretical works concerned with the computations or estimates of the ratio μ_r/μ_p, on the basis of the group—theoretical method and the huark hypothesis, we should mention the following (Coleman & Glashow 1961, Vonsovsky 1975).

In order to explain the above mentioned experiments and the anomalous magnetic moment, we will suggest a new theoretical model of the neutron, based on the unique real decay reaction of the neutron :

$$n \rightarrow p+e^-+\bar{\nu}_e. \qquad \ldots \quad (1)$$

In the present calculation the pair electron-antineutrino from (1) has the spin zero.

If the neutron is considered at rest then, due to the small amount of energy rejected during the decay (1), the proton and the electron which results have a nonrelativistic movement. If we consider that the rest mass of the neutrino is finite, and a series of experimental data plead for a very low, but finite rest mass, (Bergkvist 1972, Halprin 1975, Friedman & Smith 1958, Darries & St-Pierre 1969, Salgo & Staub 1969), with the help of the quasi-classical formalism it can be shown that the resultant moment of the electron-antineutrino system is different from that of the electron. The following formula for the magnetic moment m of two particles (Landau & Lifchitz 1970, Berestetski *et al* 1972) is used :

$$\vec{m} = \frac{1}{2c}\left(\frac{e_1}{m_1^2}+\frac{e_2}{m_2^2}\right)\frac{m_1 m_2}{m_1+m_2}\vec{M} \qquad \ldots \quad (2)$$

where $\vec{M}$ is the kinetic moment of the two particles having the masses m_1 and m_2 and the electric charges e_1 and e_2 respectively, in the Briet reference system.

If we make the substitutions :

$$\mu_{\beta}' = \frac{\vec{m}.\vec{M}}{M^2} \qquad m_1 = m \qquad \hbar \qquad m_2 = m \qquad e_2 = 0 \tag{3}$$

and taking into consideration that $m_e + m_\nu \simeq m_e$ there follows :

$$\mu_{\beta}' = \frac{e\hbar}{2m_e c} \cdot \frac{m_\nu}{m_e} \tag{4}$$

In nuclear magnetons (4) gives :

$$\mu_{\beta}' = \frac{m_p}{m_e} \frac{m_\nu}{m_e}, \mu_\beta = \frac{m_p}{m_e} \cdot \rho(\mu) \cdot \mu_\beta. \tag{5}$$

where μ_β is the value of the magnetic moment of the electron, expressed in Bohr magnetons, while $\rho(\mu)$ is a perturbational factor of non-linear type and has especially a role of a modulation or distortion factor of the electromagnetic field of the electron. The presence of the antineutrino around the electron produces a strong perturbation in the magnetic moment of the latter, because of the great difference of their finite rest masses.

The last statement results in the fact that in spite of the zero spin of the $e-\bar{\nu}_e$ system there is possible that $e-\bar{\nu}_e$ has a small (but non-zero) magnetic moment.

Let us consider now the following reactions :

$$\begin{array}{lr} \pi^- \to e + \bar{\nu}_e & (1{\cdot}24 \pm 0{\cdot}03) \times 10^{-4}\% \\ \pi^- \to \mu^- + \nu_M & \\ \quad \hookrightarrow e^- + \nu_e + \nu_m & 100\% \end{array} \qquad \ldots (7)$$

The lifetime of muon is only $2{\cdot}21 \times 10^{-6}$ s.

It disintegrates into an electron and two neutrinos. Because the coupling of the two Fermions is possible only in pairs, the relation (2) goes in (4) if one totalize for all combinations from the final states given in the reactions (7). This means that the electron-neutrino pair will be similar to a pi-meson.

In these conditions the whole kinetic moment of the system, before and after the decay, will be :

$$J = L + S. \qquad \ldots (8)$$

Here the J quantum number represents the spin of the neutron and consequently $J = 1/2$. For the S quantum number we have a fixed value $S = 1/2$ because in the combinations of the three Fermions we have taken the electron and the antineutrino anti-parallely coupled.

We will take into consideration that to the magnetic moment of the neutron, contributes the proton and the electron in a $\boldsymbol{L}.\boldsymbol{S}$ coupling perturbed by the presence of the antineutrino :

$$\boldsymbol{\mu}_n = \mu_P \boldsymbol{S} + g_y \mu_B (\boldsymbol{L} + 2\boldsymbol{S}) \frac{m_p}{m_e} \rho)\mu) \tag{9}$$

where, $\mu_P = \frac{\mu_P . S_p}{S}$, $\boldsymbol{S}_p = S$, g_y is the Landé gyromagnetic factor. Taking into consideration (5) and (8) results :

$$\boldsymbol{\mu}_n = (\mu_P + 2g_y . \mu_{B'}).\boldsymbol{J} - (\mu_P + g_y \mu_{B'})\boldsymbol{L} \quad \ldots \quad (10)$$

The value of the magnetic moment is

$$\mu_n = \frac{\boldsymbol{\mu}_n . \boldsymbol{J}}{J} = \boldsymbol{\mu}_n \frac{\boldsymbol{J}}{J^2} J$$

and thus (9) gives

$$\mu_n = (\mu_P + 2g_y . \mu_{B'}) \frac{\boldsymbol{J}.\boldsymbol{J}}{J^2} - (\mu_P + g_y \mu_{B'}) \frac{\boldsymbol{L}.\boldsymbol{J}}{J^2} J \quad \ldots \quad (11)$$

Finally we get :

$$\mu_n = \mu_P \left[J - \frac{J(J+1) + L(L+1) - S(S+1)}{2J(J+1)} \right] +$$

$$+ g_J \mu_{B'} \left[2J - \frac{J(J+1) + L(L+1) - S(S+1)}{2J(J+1)} \right] \quad \ldots \quad (12)$$

where

$$g_J = 1 + \frac{J(J+1) - L(L+1) + S(S+1)}{2J(J+1)} \quad \ldots \quad (13)$$

From (12), (13) the effective calculation of the magnetic moment of the neutron can be done paying attention to the direction of the protonic spin. We have computed the magnetic moment of the neutron using the known values of : m_ν $0{\cdot}5 \quad 10^{-3}$ MeV (Rev. particle properties 1974), $J = 1/2$, $S = 1/2$.

For $L = 0$ we have obtained $\mu_n = -2{\cdot}2010$ nuclear magnetons, which differs from the experimental value with 0·2878 nuclear magnetons. For $L = 1$ we have obtained $\mu_n = -1{\cdot}9276$ nuclear magnetons, which differs from the experimental value with 0·0145 nuclear magnetons. The deviation from the experimental value could be explained by the non-relativistic approximation in the $\rho(\mu)$ calculus. This theory is tributary to the hypothesis that the rest mass of the antineutrino is finite and to its experimental value. This theory establishes a fundamental statement that is the existence of the state with $L = 1$ and this substantiates the existence of magnetic and electric dipole moment of the neutron (Hammer & Weber 1972, Goebel 1972, Hagen & Sudarshan 1972) as well as the non-conservation of parity in the beta decay of the neutron (Vladimirsky *et al* 1961, Cristenson *et al* 1970).

References

Berestetski V., Lifchitz E. & Pitayovski L. 1972 *Theorie quantique relativiste 1-ere partie.* (MIR edit., Moscou) pp. 201.
Bergkvist K-E. 1972 *Nucl. Phys.* **B39**, 317.
Coleman S. & Glashow S. L. 1961 *Phys. Rev. Lett.* **6**, 123.
Cristenson C. J. *et al* 1970 *Phys. Rev.* **C1**, 1963.
Darries R. & St-Pierre C. 1969 *Nucl Phys* **A138**, 545.
Friedman L. & Smith L. G. 1958 *Phys Rev.* **109**, 2214.
Goebel C. J. 1972 *Phys. Rev. Lett.* **29**, 1042.
Hagen C. R. & Sudarshan E. C. G. 1972 *Phys Rev. Lett.* **29**, 1044.
Halprin A. 1975 *Phys. Rev.* **D11**, 147.
Hammer C. L. & Weber T. A. 1972 *Phys. Rev. Lett.* **28**, 1975.
Landau L. & Lifchitz E. 1970 *Theorie des champs* (MIR edit. Moscow) pp. 112
Olson D. N., Schopper H. F. & Wilson R. R. 1961 *Phys. Rev. Lett.* **6**, 186.
Review of particle properties, April 1974, Edit. CERN, Geneva
Salgo R. C. & Staub H. H. 1969 *Nucl Phys.* **A138**, 417.
Schopper H. 1961 *Phys. Lett.* **7**, 316.
Vladimirsky *et al* 1961 *Izv. Akad. Nauk. USSR*, Fys. **25**, 1121.
Vonsovsky S. V. 1975 *Magnetism of elementary particles* (MIR edit., Moscou) pp. 190.

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Photodissociation of HD$^+$ by electronic and vibrational excitations

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The interaction of photons with molecules and molecular ions is of both fundamental and practical interest. Photodissociation, which is one of the important photon-induced processes, is of great significance in the study of photochemical reactions, in modelling the ionised atmosphere (Thomas & Bowman 1974) and among others, in determining the vibrational populations of the molecular ions (Von Busch & Dunn 1972).